Physical Therapy Intervention in the Neonatal Intensive Care Unit

Eilish Byrne¹ & June Garber²,³

¹Neonatal Intensive Care Unit, Lucile Packard Children’s Hospital, Palo Alto, CA, USA, ²Neonatal Special Care Nurseries, Emory University Hospital Midtown and Grady Memorial Hospital, Atlanta, GA, USA, ³Division of Physical Therapy, School of Medicine, Emory University, Atlanta, GA, USA

ABSTRACT. This article presents the elements of the Intervention section of the Infant Care Path for Physical Therapy in the Neonatal Intensive Care Unit (NICU). The types of physical therapy interventions presented in this path are evidence-based and the suggested timing of these interventions is primarily based on practice knowledge from expert therapists, with supporting evidence cited. Physical therapy intervention in the NICU is infant-driven and focuses on providing family-centered care. In this context, interventions to facilitate a calm behavioral state and motor organization in the infant, address positioning and handling of the infant, and provide movement therapy are presented.

KEYWORDS. Physical Therapy, Neonatal, Intervention, Therapy, NICU

This article describes the physical therapy interventions included in the Infant Care Path for Physical Therapy in the Neonatal Intensive Care Unit (NICU) (Figure 1, Campbell, 2013). The types of physical therapy interventions included in the Infant Care Path for Physical Therapy in the NICU are evidence-based. The suggested timing of these interventions was primarily driven by practice knowledge, with evidence regarding timing cited as available. The suggested time line for interventions was developed with input from five expert therapists across the country, allowing for regional representation regarding neonatal physical therapy practice. For a more thorough discussion of the development and use of care paths in general, please refer to the article entitled “Use of a Care Path” (Campbell, 2013). This article will present interventions for facilitating a calm state and motor organization, positioning and handling of the infant, and providing movement therapy. The context for providing these interventions includes a developmentally appropriate, family-centered approach to care where environmental challenges are considered.

Address correspondence to: Eilish Byrne, Neonatal Intensive Care Unit, Lucile Packard Children’s Hospital, Stanford University, 725 Welch Road, Rehabilitation Services – 3rd Floor, Palo Alto, California 94304, USA (E-mail: ebyrne@lpch.org).

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This article begins with a discussion regarding the contexts in which the interventions occur.

**INFANT-DRIVEN, FAMILY-CENTERED APPROACH**

Providing developmentally appropriate care to infants and families in the NICU requires a dynamic, continuous approach to intervention. Relationship-based (infant driven), family-centered caregiving is a critical element of developmental care.
Physical therapists in the NICU promote developmental relationship-based care of the infant. To accomplish this, the physical therapist provides interventions to facilitate infant development while collaborating with the parents to support their needs to engage with and parent their infant.
Providing and modeling relationship-based care of the infant requires that the physical therapist not only recognize, but also respond appropriately, to infant behavioral cues (Als et al., 2003). It is through responding appropriately to infant cues during care that development of behaviorally beneficial neuronal pathways is supported in the infant through modulation of the infant’s neurobehavior (Als et al., 2004). A useful model of infant behavior to guide physical therapy care in the NICU is the synactive model of infant development (Als, 1982) in which interdependent behavioral dimensions are organized as subsystems and affect infant neurobehavior. These subsystems include the autonomic system, the motor system, the state organizational system, the attentional-interactive system, and the self-regulatory system. In using this model, the physical therapist observes whether the five subsystems are working well together to provide the infant with physiologic stability and the ability to engage in social interactions. If the physical therapist recognizes that the infant is communicating signs of stress, the appropriate response is to identify the stressor and eliminate it if possible.

The Newborn Individualized Developmental Care and Assessment Program (Als, 1982) is a developmental care framework that can be used in the NICU setting to help guide caregiver–infant interactions. For instance, the physical therapist should schedule sessions at a time that is most appropriate for the infant and family, as well as in conjunction with the bedside nurse’s schedule for routine care and feeding. Typically, services are delivered prior to a scheduled feeding. Respecting an infant’s right to sleep (and need for recovery from handling) is an important aspect of providing developmentally focused care. Deep sleep is important for the development of the neurosensory system and the maturing brain (McGrath, 2007). Some research findings have been supportive of this model of health care delivery. In a study examining outcomes of infants born preterm receiving an individualized developmental care and assessment program, Peters et al. (2009) found significantly improved short- and long-term function, reduced length of stay, reduced incidence of chronic lung disease (CLD), and decreased mental delays at 18 months corrected age (CA).

There are many factors in the NICU environment that challenge not only the neurodevelopment of the infant but also the development of the parent–infant relationship. In the NICU, the infant is exposed to fluctuations in noise levels, temperature, light, and schedules of evaluation and care. The infant may endure noxious stimuli, painful procedures, pharmacologic agents, and too much handling at times. Risk for infection can be high, threatening the health of the infant. It is under these circumstances, too, that family bonding can be threatened. During the crisis of having an infant hospitalized in the NICU, parents may experience feelings of anxiety, helplessness, loss of control, fear, uncertainty, and worry (Miles & Holditch-Davis, 1997). These feelings can impact the parent–infant interaction.

A physical therapist provides relationship-based care to the family by fostering the parent–infant relationship. One model for doing this is the hope-empowerment model (Sweeney & Swanson, 2001) by which the physical therapist builds a therapeutic partnership through collaboration with the parent to assist with coping and foster empowerment. In addition to addressing the physical therapy needs of the infant, physical therapists have a unique opportunity to collaborate with parents through instruction and guidance regarding infant handling and positioning.
appropriate developmental activities (e.g., tummy time for play, reaching activities), and recognition of infant cues and behavior. Instructing parents on how to safely handle and position their young infants with skill and confidence is a role of the physical therapist in the NICU (Sweeney, Heriza, & Blanchard, 2009). Learning and practicing these skills with a physical therapist may increase a parent’s ability to participate in infant care, and proponents of family-centered care advocate that appropriate parental involvement will benefit the current and future health of the infant (Gale & Franck, 1998).

Physical therapists provide family-centered care by understanding how comfortable the parents are regarding participation in their infant’s care. A model to assess this defines four levels of participation (Karen I. Wayman, personal communication, October 2010). Level 1 is a medical approach in which information is provided to the family. Level 2 is a family support approach in which the family may be offered individual or group support for coping and decision making. Level 3 is family involvement and partnership in care, and Level 4 is family efficacy. Achieving family efficacy implies that there is a shared decision-making process in the care of the infant. Other components of the therapist–parent relationship to address when delivering family-centered care include respect, collaboration, and support (Hutchfield, 1999). For a more detailed discussion of family-centered care and the parent–infant and parent–therapist relationships, please see the article entitled “Family Support and Education” (Goldstein, 2013).

ENVIRONMENTAL CONSIDERATIONS

The environment of the NICU is not inherently conducive to neonatal growth and development. In fact, excessive environmental stimuli experienced by the preterm neonate may contribute to developmental concerns that emerge at school age (Perlman, 2001). Primary environmental considerations include facilitating neonatal temperature regulation, modifying environmental lighting, and limiting noise levels. In most nurseries, neonatal temperature regulation is maintained through the use of an incubator (isolette). Temperature regulation contributes to neonatal physiologic stability and energy conservation. To promote temperature stability, the incubator thermostat is set to provide the heat needed to help the neonate maintain a minimum temperature of 36.5°C. When providing physical therapy in the NICU, it is important to know that the infant’s temperature is within appropriate limits prior to removing the infant from the incubator or removing infant clothing and to assess the effects of handling on infant thermal stability.

Lighting in a NICU is bright compared to the darkness of the intrauterine environment; the infant rarely experiences total darkness. In fact, the infant will likely experience exceptionally bright overhead lights during a variety of medical procedures. Although bright lights may be needed for certain medical procedures, the infant born preterm is unable to independently modulate this experience. The use of cycled lighting in a NICU to facilitate the development of the neonatal circadian clock (Rivkees, Mayes, Jacobs, & Gross, 2004) and to promote weight gain for low birth weight infants (Jung, 2005) has been advocated, although research is not conclusive. When removing the infant from an isolette for developmental stimulation, the physical therapist should be careful to keep the infant comfortable and, when
possible, the environment should be modified to facilitate infant success at a particular developmental task (e.g., dim the lights when facilitating visual interaction).

Modulating the noise in a NICU is important for promoting optimal neonatal development. High noise levels may contribute to neonatal physiologic stress. Stimulation from alarms and other external noises can produce neonatal autonomic responses, compromising physiologic stability (Bremmer, Byers, & Kiehl, 2003). Short-term physiologic responses to elevated noise levels may include changes in heart and respiratory rates (Wharrad & Davis, 1997). These short-term changes may utilize more energy, limiting the capacity for growth and healing (Brown, 2009). In addition to the short-term effects of elevated noise, some researchers express concern that prolonged exposure to uninterrupted noise in the NICU may contribute to long-term hearing deficits (Brown, 2009; Levy, Woolston, & Browne, 2003).

Some ways to curb unnecessary noise in a NICU include instituting “quiet times,” closing incubator portals quietly, avoiding tapping on incubators, lowering your speaking voice and limiting bedside conversation, eliminating unnecessary overhead paging, silencing alarms when able to, and installing sound-absorbing flooring and fixtures or sound-activated signaling systems to indicate the need to reduce sound levels. For the physical therapist, targeting unit “quiet times” to work with the neonate outside of the incubator may foster neonatal self-regulation.

**FACILITATE CALM STATE AND MOTOR ORGANIZATION**

The first item addressed in the Intervention section of the Infant Care Path for Physical Therapy in the NICU (Campbell, 2013) is behavioral state regulation and the interventions to facilitate a calm state and motor organization, including non-nutritive sucking (NNS), containment, and positioning (including hydrotherapy and “skin-to-skin care”; SSC) (Figure 2). Noxious sensory inputs that an infant born preterm experiences in the NICU negatively affect the neuronal organization that normally occurs in the last trimester of pregnancy (Als et al., 2004). Noise, bright lighting, and touch can cause physiologic instability and stress and adversely affect development of the preterm infant (Als et al., 1994; Anand & Scalzo, 2000). For the infant born preterm, physiologic stability (e.g., heart rate of 120 to 180 beats per minute, oxygen saturation approaching 100%, and respiratory rate of 20 to 50 breaths per minute) enables quiet alert states and behavioral organization for social interaction and functional motor patterns (e.g., hands to midline). It is important to note that signs of physiologic stability should be evaluated within the context of the neonate’s day and individual medical status. Techniques that help the neonate to maintain physiologic stability decrease attention difficulties in infancy (Buehler, Als, Duffy, McAnulty, & Liederman, 1995). Based on documentation of an infant’s competencies and needs, a variety of techniques can be used to help an infant find a calm, quiet, and organized state. These include sucking, contained and supportive touch, positioning to foster flexion, midline placement of the infant’s extremities, and using slow transitional movements (Als et al., 1994; Buehler et al., 1995).

**Non-Nutritive Sucking (NNS)**

Non-nutritive sucking includes placement of an appropriately sized pacifier or a caregiver’s gloved finger within the infant’s mouth to elicit at least some degree
of sucking effort, with minimal fluid other than oral secretions to control. As an intervention method for fragile preterm infants, NNS is initially elicited while the relatively alert infant remains in an isolette in prone or sidelying prior to or during gavage feeding. Within an infant’s tolerance of handling and ability to maintain temperature stability, NNS can be facilitated while that infant is held by a parent during a gavage feeding or at the mother’s emptied breast during “kangaroo care” or “SSC” (Kirk, Alder, & King, 2007).

The NNS experience benefits a preterm infant in multiple ways. Infant’s responses to this oral experience reflect their degree of fatigue as well as their neuro-motor maturity. Among infants less than 33–34 weeks postmenstrual age (PMA), NNS consists of short bursts of licking and usually leads to restful sleep periods. Among more mature preterm infants, NNS is a more complex motor pattern that not only helps them calm to sleep when tired but also helps them achieve periods of quiet alertness. For parents providing NNS, these positive responses from their infants contribute significantly to early relationship building and their sense of competence as parents. In preparation for the demands of oral feeding, NNS experience can improve the strength and control of oral musculature as well as improve the infant’s rooting or oral orientation responses (Boiron, Da Nobrega, Roux, Henrot, & Saliba, 2007). These topics are discussed in more detail in the article entitled “Oral Motor Function and Feeding Intervention” (Garber, 2013).

**Containment**

Containment and touch also facilitate self-regulation in the neonate. When applied by caregivers, facilitated tucking (where the infant is held in a sidelying fetal position by the parent) was equal to or better than other pain management techniques after uncomfortable procedures such as heel stick or pharyngeal suctioning (Axelin, Salantera, Kirjavainen, & Lehtonen, 2009). Contained touch in the NICU typically involves placing a firm (not too soft, not too hard) hand on the neonate at the top of the head and over the trunk and hip area to flex the hips, thereby “containing” the infant. It is thought to be most effective for infant calming when the caregiver’s hands are still and not moving. This technique can be performed as tolerated until the infant is calm/relaxed or sleeping.

Swaddling, a containment positioning technique that facilitates flexion, can foster self-regulation of the infant (Neu & Browne, 1997). Swaddling typically involves wrapping a blanket around the infant in such a way as to help the infant maintain gentle flexion of the legs and arms without eliminating small arcs of spontaneous movement. Swaddling provides support through the infant’s trunk and therefore is a useful positioning technique for breast and bottle feeding, for transitions in and
out of bed, and for periods of interaction with parents. In a study by Franco et al. (2005), term infants in supine had better sustained sleep and reduced spontaneous awakenings during non-rapid eye movement sleep. In addition, the infants slept longer and spent more time in non-rapid eye movement sleep. Swaddling in sidelying and supine was also found to facilitate neuromuscular development (Short, Brooks-Brunn, Reeves, Yeager, & Thorpe, 1996).

Prone and sidelying positions can also provide containment. Among fragile infants less than 32 weeks PMA, placing infants in these positions inside an isolette or on a caregiver’s chest has been shown to facilitate extremity flexion toward the midline, limit uncontrolled flailing extremity movement, and encourage more stable vital signs (Axelin et al., 2009; Heimler, Langlois, Hodel, Nelin, & Sasidharan, 1992). In addition, when compared to supine, the prone and left sidelying positions decreased the occurrence of reflux from gastroesophageal reflux disease (GERD) in these infants (Corvaglia et al., 2007). Utilizing prone and sidelying positions allows infants born preterm to recover from stressful events and calm to sleep better than in a supine position while being monitored (not appropriate for home). Among more vigorous preterm infants 32–34 weeks PMA, the prone and sidelying positions can also extend the duration and improve the quality of emerging interactive responses.

Sidelying also may facilitate chin tucking for the development of head control and arm and hand movements for hand to mouth/face play and hand to body play, activities that are self-regulatory behaviors (Grenier, Bigsby, Vergara, & Lester, 2003). Likewise, placing neonates in the sidelying position may foster motor organization as demonstrated by more coordinated spontaneous midline movements (Nakano et al., 2004). The supine position has been generally seen as less supportive to the preterm infant’s state regulation and comfort. However, when the goal is to vary the infant’s positioning experience and promote musculoskeletal integrity in supine or when the supine position is preferred medically, using a developmental nest may contribute to better coordinated, midline-oriented movements of the upper and lower extremities (Ferrari et al., 2007).

**Skin-to-Skin Care (SSC)**

Skin-to-skin care is a positioning technique with particular benefits to the infant and parents. The diapered-only infant is nestled under the parent’s shirt directly against the skin and then a blanket is placed over the infant and parent. When implemented correctly, this position promotes soft flexion of the infant’s arms, legs, trunk, and neck. The immediate benefits for self-regulation may include temperature regulation, improved oxygen saturation, and decreased respiratory rate (Fohe, Kropf, & Avenarius, 2000). With support and instruction, parents learn to relax with their infant snuggled in this manner; they learn to provide appropriately low levels of stimulation; and they feel valued as providers of this important intervention. SSC is associated with decreased length of hospital stay, improved weight gain, and increased frequency of breast feedings at discharge (Bier et al., 1996; Wahlberg, Affonso, & Persson, 1992). In addition, Bier et al. (1996) found that, out of a group of mothers who intended to breast feed their infants, significantly more mothers who performed SCC compared to standard holding (clothed and blanketed infant) were still breast feeding after one month post-discharge. Regarding
infant development and maternal health, Feldman, Eidelman, Sirota, and Weller (2002) found that infants who received frequent SSC from their mothers had a better developmental outcome at six months CA and mothers were less depressed.

**Hydrotherapy**

Hydrotherapy with a swaddled infant may be a useful adjunct intervention for facilitating self-regulation. Benefits of hydrotherapy in other patient populations (adults) may include relaxation, decreased pain, improved perceived quality of life (Tinti, Somera, Valente, & Domingos, 2010), and increased cardiorespiratory and renal functions (Pechter, Maaroos, Mesikepp, Veraksits, & Ots, 2003a; Pechter et al., 2003b). Neonates have demonstrated physiological tolerance of hydrotherapy provided by a physical therapist (Sweeney, 1983). In addition, infants 32–36 weeks PMA who received swaddled hydrotherapy (for details on the swaddled emersion protocol, please refer to the article) prior to feeding demonstrated improved feeding efficiency (Sweeney, 2003).

The Infant Care Path for Physical Therapy in the NICU (Campbell, 2013) indicates that techniques for facilitating a calm state and motor organization are appropriate throughout the NICU stay, but should be adapted appropriately as the infant develops, the infant–parent relationship grows, and discharge approaches.

**POSITIONING AND HANDLING**

The second item addressed in the Intervention section of the Infant Care Path for Physical Therapy in the NICU (Campbell, 2013) is positioning and handling (Figure 3). Specific topic areas in this section include preserving musculoskeletal integrity, and promoting comfort, respiratory function, skin integrity and contained movement, splinting, range of motion, and infant alerting. The musculoskeletal system of infants born preterm is vulnerable to the effects of gravity, poor handling (not properly supporting the infant) and positioning, and the restrictions caused by necessary medical equipment such as boards to hold intravenous lines in place. Physical therapists have an important role in ameliorating some of the potentially deleterious effects of these experiences. Because infants born prior to 31 weeks gestational age (GA) have immature muscle fibers and neuromuscular junctions (Lowes, Sveda, Gajdosik, & Gajdosik, 2012) and diminished flexor tone (Grant Beuttler & Shewokis, 2007), developmentally supportive positioning is important. Allen and Capute (1990) described tone development in the infant born preterm to be caudo-cephalad, beginning at about 33–35 weeks PMA in the lower extremities and 35–37 weeks PMA in the upper extremities. The physical therapist needs to position the infant in a manner that facilitates this developmental progression. Sweeney and Gutierrez (2002) suggest that the neck, shoulders, hips, and feet are particularly vulnerable to the effects of poor positioning and infants born preterm may experience neck hyperextension, shoulder retraction, external rotation of the hips, and foot eversion when positioned in supine or in prone (without appropriate developmental rolls).
FIGURE 3. Positioning and Handling, Intervention section of the Infant Care Path for Physical Therapy in the NICU. Source: Campbell (2013).

Head Shaping and Musculoskeletal Integrity
Varying the position of the infant is important for maintaining musculoskeletal integrity and avoiding contracture and deformity including acquired torticollis (Sweeney & Gutierrez, 2002; Vaivre-Douret, Ennouri, Jrad, Garrec, & Papiernik, 2004), assisting with skull shaping (Najarian, 1999; Neufeld & Birkett, 2000; van Vlimmeren et al., 2008), and providing varied visual stimulation. Varying the infant’s position refers to placing the infant in prone, sidelying, supine, and supported upright regularly throughout the day (ideally) or over the course of a few days. When placing the infant in any of these positions, the physical therapist should take care to facilitate neutral alignment of joints, support the head and spinal curves, and encourage midline orientation of extremities and opportunities to appropriately visually interact with the environment.

A case report by McManus and Capistran (2008) illustrates a positioning program implemented in the NICU to promote head shaping of an infant born preterm with dolichocephaly. Dolichocephaly, which is a head with narrow width and long anterior-posterior cranial distance, is commonly seen in infants born preterm. It is important to address in the NICU because it often persists after discharge and may require substantial physical therapy intervention. In this case report, the infant was placed on a viscoelastic mattress with a developmental care program in place. Cranial molding was measured using the cranial index, a ratio of width to length. After implementing a positioning program to foster midline head position, the cranial index measurements improved to within normal limits. This effect was maintained at the time of discharge. This case highlights how a physical therapist can prevent musculoskeletal impairment of preterm infants in the NICU.

Promote Comfort and Respiratory Function
Placing infants in certain positions can promote self-regulation and physiologic stability. SSC promotes autonomic regulation (as previously described) and improved oxygenation in infants born early (Cleary, Spinner, Gibson, & Greenspan, 1997). Likewise, compared to the supine position, the prone position is associated with decreased central apnea and periodic breathing (Heimler et al., 1992) and is also therefore considered to promote stability in neonatal respiration (Levy et al.,
Levy and colleagues (2006) also noted that prone positioning among healthy preterm infants approaching discharge no longer provided a pulmonary advantage over supine. As reflected in the NICU Care Path at 34 weeks PMA, infants without gastroesophageal reflux and/or chronic pulmonary insufficiency can begin the transition to increased supine sleeping time. The prone position is also considered to promote general infant comfort, as infants typically “settle” in this position. In addition, as previously mentioned, sidelying flexion helps infants calm after painful procedures (Axelin et al., 2009).

**Promote Skin Integrity and Provide Scar Management**

Promoting the skin integrity of the neonate is a role for the physical therapist in the NICU. Healthy skin requires nutrition and oxygen-rich blood. Physical therapists can intervene in ways that facilitate the flow of blood to areas of skin at risk for compression due to body position and gravity. Interventions performed by the physical therapist may include facilitated or passive movement of limbs, positioning changes of head/neck, trunk, or limbs, and use of pressure-relieving aides as appropriate. In a study by Marcellus (2004), the bodily area experiencing the greatest amount of pressure in supine, prone, and sidelying was the head (in all three positions), followed closely by the knee in prone and shoulder in sidelying. Special attention to these areas during developmental positioning is warranted, as the skin of the infant born preterm is more prone to dryness and injury. In addition, the results by Marcellus (2004) emphasize the importance of promoting a variety of well-tolerated positions to be used throughout the day within the context of a developmental program.

Scar management as a component of promoting skin integrity can be a role for the physical therapist in the NICU, but the evidence supporting the best method for this intervention is mixed. Part of what makes evaluating the evidence for scar management difficult is the variety of techniques studied (e.g., silicone gel, silicone gel sheeting, topical medicines, scar massage), the differences in the types of injury studied (e.g., trauma, burns, medical burns), the differences in the age of the skin injury (recent skin injury or old skin injury), and the variety in patient age from newborn to elderly. Due to the heterogeneity of studies, a best method for injury characteristics and patient age has not been established.

A Cochrane review to assess the efficacy of using silicone gel sheeting to treat and prevent scarring in other patient populations (O’Brien & Pandit, 2006) found that most clinical trials were (1) small, (2) of poor quality, and (3) highly susceptible to bias. Since this review, a variety of studies have shown benefits to using a variety of treatment methods including, silicone gel sheeting (Karagoz, Yuksel, Ulkur, & Evinc, 2009; Sakuraba, Takahashi, Akahoshi, Miyasaka, & Suzuki, 2011; Wigger-Albert et al., 2009), topical silicone gel (Karagoz et al., 2009), pressure garments (Engrav et al., 2010), and a combination of these therapies (Li-Tsang, Zheng, & Lau, 2010). As no single best method for scar management has been identified, the therapist will need to collaborate with the health care team in identifying the best intervention for a particular patient situation in the NICU and should be vigilant in following the literature to identify the most appropriate evidence-based strategies.
**Promote Contained Movement**

The promotion of contained movement is another component of developmentally appropriate positioning and handling of preterm infants with limited endurance and immature capacity to control more complex antigravity movement. This intervention differs from the previously discussed calming measure referred to as containment. Contained movement refers to free movement with boundaries that typically limit the motion within mid-range for protection and support. Regardless of age, most medically fragile infants with limited tolerance of handling can benefit from promotion of contained movement during their positioning and routine care. The cycles of active movement that are typically evident to mothers during their third trimester of pregnancy play an important role in fetal musculoskeletal and nervous system development. Fetal ultrasound images during the third trimester of pregnancy confirm that movements are typically vigorous, complex, and variable while being limited in range by the uterine wall. The rationale for promotion of contained movement is provision of a similar though diminished developmentally significant experience. Using the qualitative assessment of General Movements developed by Prechtl and colleagues, a variety of smooth, multi-directional fetal movements of the head, trunk, and extremities were observed in utero as well as among infants born preterm as young as 24 weeks PMA (de Vries & Bos, 2010; Prechtl, 1990). The uterine wall not only limits the arcs of extremity movements, but also facilitates flexed resting postures between cycles of fetal movement.

When prematurely born infants are at rest and not being disturbed by caregivers, nested bedding is the primary uterine wall substitute for support of flexed postures, midline orientation, and limitation of extremity movement. A study comparing the posture and movement responses of preterm infants demonstrated benefits of nested support (Ferrari et al., 2007). The positioning method used by Ferrari et al. (2007) consisted of a relatively deep oval nest completely surrounding the infant from head to toe with space for movement while supine. The authors concluded that when “nested,” infants not only maintained resting postures with greater extremity flexion, but also initiated spontaneous movements with more midline orientation and isolated distal components as well as initiated fewer abrupt or end range extremity extension movements. The primary effect among 30–33 weeks PMA infants supported by nested bedding was increased extremity movements toward the midline and isolated distal movements of the wrists. Among infants 34–36 weeks PMA, abrupt, spontaneous startle movements were significantly decreased as an additional benefit. A finding specific to infants at 37–40 weeks PMA was resting postures before and after spontaneous movement that included increased shoulder adduction and head alignment in midline.

During routine care of preterm infants <35 weeks PMA, several rest periods with containment measures provided by the hands of a caregiver are typically needed for calming while vital signs return to baseline levels. Smooth, small-arc movements of extremities toward the midline and active trunk flexion signal not only a preterm infant’s recovery from the stress of routine care measures but also a drive to move and enjoyment of controlled movement. When these behaviors are observed, brief uninterrupted periods to engage the infant in free but contained movement can be of benefit. For example, an infant supported in a flexed sidelying position with a
surface against which to kick (adult’s hand) can experience variable, smooth movement typical of <35 weeks PMA infants. By modeling this technique, a therapist introduces caregivers to options other than swaddling that may significantly limit developmentally important extremity movement.

**Provide Gentle Range of Motion as Indicated and Splinting as Needed**

Some infants born preterm require gentle range of motion due to contracture or prolonged immobility (e.g., the very ill infant sedated and “paralyzed” for recovery). As an expert in the musculoskeletal system, the physical therapist is qualified to provide this intervention, but the neonatal musculoskeletal system is fragile and vulnerable to injury. Providing passive range of motion can put the neonate at risk for fractures (Dabezies & Warren, 1997). A special consideration for infants born preterm is that they have cartilaginous joints at the wrists and ankles (Buckwalter, 1994). In addition, infants born preterm are at greater risk for developing osteopenia. Clinical evidence of mineral bone deficiency has been demonstrated in 30–50% of infants born with very low birth weight (VLBW) who are fed unfortified human milk (Hawthorne, Griffin, & Abrams, 2004; Koo et al., 1988), so particular care must be taken when providing range of motion. Often in consultation with occupational therapy, splinting is reserved for contracted joints or used as an immobilization aide as needed (e.g., to stabilize fractures; Dabezies & Warren, 1997).

**Facilitate Periods of Exploratory Moving**

The promotion of exploratory movement without boundaries is another important component of developmentally appropriate positioning and handling. With proximal support, maturing preterm infants benefit from unrestrained movement with the demands of gravity reduced. Strength and control gained by exploratory movement experience form a bridge for the infant to begin more complex antigravity movement.

With trunk and neck support provided in supine, prone, or sidelying positions, a preterm infant can enjoy the freedom to move one or more extremities without boundaries imposed by blankets, nested bedding, or caregiver’s hands. In supine lying, support of the head in midline and containment of the upper extremities close to the trunk can enable an infant to explore a wider variety of lower extremity movements than otherwise tolerated. Also in supine lying with containment of all the extremities, provision of a neck roll can encourage an infant to engage in side-to-side neck rotation, orientation to voices, and to briefly hold a midline position. While sidelying with trunk support, the un-weighted upper arm and leg are free to move. Initially, preterm infants typically respond best to free movement of only one arm or leg in this position. Some infants find horizontal sidelying particularly challenging and often more so on one specific side. Poor tolerance of sidelying can be due to restricted expansion of the lower, weight-bearing rib cage, delayed gastric emptying, or gastroesophageal reflux. Elevation from horizontal sidelying or supine lying on a firm surface to a 30–40 degree angle can allow improved expansion of the rib cage as well as relieve gastric problems (van Wijk et al., 2007). Exploratory movement in supine lying is more demanding than in prone for infants with pulmonary insufficiency requiring supplemental oxygen. In prone position, infants who are oxygen-dependent have higher lung volumes and functional residual capacity.
that improves oxygen saturation and reduces the effort of breathing (Bhat et al., 2003). Among healthy preterm infants, however, the cardiopulmonary demands of different positions seem to be clinically insignificant (Dolberg, Yacov, Mimouni, & Barak, 2004; Levy et al., 2006). In prone lying with head, neck, and trunk ventrally supported as well as elevated off the support surface to shift weight off the lower extremities, infants can explore kicking without boundaries to push against. In prone lying at 30–40 degrees incline, stabilization of the extremities close to the trunk can allow an infant to explore head lifting with variable degrees of rotation.

**Promote Alerting and Interaction**

Promoting infant alerting for various developmental tasks such as feeding, environmental exploration, and social interaction with family is a role for the physical therapist in the NICU. Facilitating infant state regulation so that the infant achieves a calm alert state (Brazelton Level 4) can be done through various interventions (Brazelton & Nugent, 1995). Researchers have shown that a carefully implemented program consisting of auditory (soothing voice), tactile (massage), visual (attempted eye contact), and vestibular (horizontal rocking; ATVV) stimuli can promote alerting in healthy convalescing preterm infants (White-Traut, Nelson, Silvestri, Cunningham, & Patel, 1997; White-Traut, Nelson, Silvestri, Patel, & Kilgallon, 1993). This research (please refer to the articles for more detail regarding the protocol used) has since been expanded to include extremely preterm infants (born at 23–26 weeks GA) and preterm infants with intracranial lesions (White-Traut et al., 2002). In the latter study, the infants receiving ATVV demonstrated significantly increased alerting during the intervention that was significantly correlated with reduced length of stay. In addition, the proportion of nipple feeds increased significantly faster for infants in the study group than those in the control group (White-Traut et al., 2002).

Despite these positive findings, the therapist must take care not to overstimulate the infant or create physiologic instability. Sensitivity to infant behavioral and physiologic cues is critical. In addition, it is necessary for the therapist to remember that a preterm infant may have a delayed reaction to an intervention so one should ascertain the effects on sleeping patterns and feeding after the stimulation. When implementing an ATVV program to encourage infant alerting, it should be noted that White-Traut et al. (1997) found that tactile stimulation alone was too stimulating and that the vestibular component helped modulate the overall sensory experience of the preterm infant.

**MOVEMENT THERAPY**

It is important for the infant to have opportunities for movement, both guided and facilitated and self-initiated (with protective boundaries). These movement opportunities are provided in the context of varying the infant’s position (e.g., supine, sidelying, prone, supported upright). The next section of this article presents physical therapy interventions from the Movement Therapy portion of the Infant Care Path for Physical Therapy in the NICU (Campbell, 2013; Figure 4).
Guided Extremity Movements

Development of strength may be facilitated by guided flexion and extension movements of the infant’s lower extremities, similar to a bicycle riding pattern, initially performed with hands placed around the knee joint for protection. During this activity, as the infant begins to actively kick, the physical therapist’s hands move to the plantar surface of the foot in order to give tactile and proprioceptive input as the infant gently kicks. This provides the infant with a surface to extend against. This movement does not involve traction or joint compression, and it is not explicitly resistive. The maneuver is meant to mimic what infants experience when pushing against the intrauterine wall. The purpose of this exercise is to facilitate both free kicking and guided contained kicking, movements the infant is free to perform in utero, but that are limited by the constraints of swaddling and the force of gravity in the NICU. These flexion and extension movements of the legs may be beneficial for joint molding, because after birth infants born preterm do not experience the resistance of the fluid-filled utero environment (Sweeney & Gutierrez, 2002). In addition, the opportunity for the infant to gently push against their parent’s hand (similar to pushing against the intrauterine wall) may help decrease bone demineralization (Litmanovitz et al., 2003; Moyer-Mileur, Brunstetter, McNaught, Gill, & Chan, 2000), as research showed that guided range of motion exercises for VLBW infants decreases osteopenia.

Increased Time in Upright Position

The infant’s tolerance of upright positioning is important for multiple caregiving situations. Supported sitting is developmentally beneficial because it will (1) facilitate the use of the neck rotator and extensor muscles, which may foster development of head control; and (2) promote an alert and visually oriented behavioral state (Sheahan & Brockway, 1994). Prior to 35 weeks PMA, most preterm infants initially experience the upright position for brief periods during routine care within their isolette and while being held by a parent or other caregiver. Schrod and Walter (2002) investigated concern that movement from horizontal lying to vertical is associated with orthostatic stress in fragile preterm infants. Reassuringly, they reported no clinically significant autonomic or cerebral oxygenation effects among infants less than 1,500 g during the first week of life at 30 degrees elevation of the whole body.
FIGURE 5. This position provides upright support of the infant facing away from the caregiver with their back and head against the caregiver's chest and anterior support of the infant's chin and trunk provided by the caregiver's hand. In response to this support, the infant pictured is actively bringing her head toward vertical midline.

At approximately 35 weeks PMA, preterm infants typically increase their upright position time as they gain competence in nipple feeding. With experience and maturation, the infant's responsive periods during supported sitting can expand from 1 min to 2 min in the middle of a feeding to 10–15 min periods following feeding several times each day. With trunk support and freedom to move in supported upright, spontaneous head righting effort and exploratory movements with extremities can gradually increase in frequency and duration. While a swaddled infant is held by a caregiver, there are many variations of upright positioning that can be used. Typically, the most easily tolerated position for an infant is upright prone at the caregiver's shoulder. Another involves upright support of the infant facing away from the caregiver with their back and head against the caregiver's chest and anterior support of the infant's chin and trunk provided by the caregiver's hand (Figure 5). A supportive type of semi-upright lap sitting requires the caregiver's feet to be elevated by a stool in order to provide the infant with full posterior support of their head and trunk while looking toward the caregiver. Supported lap sitting from semi-upright to full upright with the adult's hands providing variable degrees of anterior and posterior trunk and neck support is the most challenging for young infants (Figure 6).

As infants' interest in the world around them exceeds the time parents, staff members, and even volunteer caregivers have available to hold them upright, use of infant seats and swings often begins. These devices have both advantages and disadvantages that should be acknowledged by nurses and therapists as well as explained.
FIGURE 6. While full trunk support is provided by adult hands, gentle lifting of the upper trunk aligns the spine in vertical, limits increased pressure on the stomach, and elongates muscles of the trunk. This can in turn facilitate head righting and interactive orientation responses as well as burping.

to parents. The seats frequently need positioning devices or multiple blanket and diaper rolls to maintain midline alignment of the infant’s neck and trunk as well as support their shoulder and pelvic girdles. Young infants can tire rapidly in these seats and with fatigue their tolerance of environmental and social stimulation decreases. With supportive positioning and gradually increasing time in these devices, young infants can benefit from the increased upright positioning time in swings and infant seats. Once infants gain endurance for upright positioning, they may begin to modulate postural responses as well as alter their extremity movements as the degree of external trunk support and the angle of sitting change. As infants increase their time in upright positions, therapists can instruct parents to observe signs of their infant’s maturing movement control as well as fatigue and discuss the value and drawbacks of time spent in swings and infant seats following hospital discharge. Investigating the relationship between infant play-equipment use, favored play positions, and motor development, Bartlett and Kneale-Fanning (2003) found that following hospital discharge, a large percentage of preterm infants spent more time sitting in swings and infant seats as well as carried in a sitting position than other play positions. The authors were unable to identify a cause versus effect
Byrne and Garber

relationship, but concluded that lack of sitting ability contributed to an infant’s preference for prolonged carrying or supportive seating while the extended periods of carrying and equipment use limited the infant’s opportunities for development of independent sitting ability.

Varied Developmental Positions

Although preterm infants benefit from spending gradually increasing time in supported upright positions, they should experience movement in prone, supine, and sidelying to promote motor development and prevent secondary impairments such as plagiocephaly and torticollis. Preterm infants 35 weeks PMA and older spend increasing amounts of time sleeping in supine and feeding in supported upright positions. Consequently, effort may need to be directed toward providing the infant experiences moving in prone and sidelying.

One strategy that we have found successful is to vary the position in which the infant is held, especially by their parents. When providing SSC in semi-upright prone, the direction the infant faces should be alternated between right and left, especially if the infant prefers rotation to one side. Infants also benefit from variation in cradled holding positions. Right-handed caregivers tend to hold infants with their left arm, leaving their more dexterous right hand free for manipulative tasks. An infant cared for by primarily right-handed people can become adept at orientation to voices and movement toward their own right side while ignoring the majority of input from the left (Hummel & Fortado, 2005). These caregiving patterns with unidirectional stimulation can contribute to the progression of plagiocephaly. Although it feels awkward initially, encouragement of right-handed parents to cradle the infant with their right arm provides that infant with social stimulation to which they can respond from the left side.

As infants begin to lift their head while held against a caregiver’s shoulder, this righting response is optimally facilitated from each of the adult’s shoulders. Immature head righting effort is often characterized by rotation to one side rather than a midline position. While lifting their head, infants also tend to rotate toward the direction of their caregiver’s voice or face. The pattern of simply placing an infant with their head at opposite ends of their bed every other day or following each feeding during the day is helpful to present different environmental stimulation and aid bilateral orientation by the infant. As previously mentioned, sitting with trunk support from a caregiver is a very different task for an infant than upright placement in a swing or infant seat with either a molded plastic or a cloth hammock seat. Nevertheless, each of these positions provides a variety of postural challenges for an infant, opportunities for antigravity upper extremity movement, and engagement with social or environmental stimulation from varied directions.

Before discharge from the NICU, the majority of preterm infants enjoy semi-prone snuggling and movement on a caregiver’s lap or chest. The challenge of prone head righting is reduced and head lifting to find a familiar voice is more easily facilitated in this semi-prone position at approximately a 45 degree angle. Time for continuation of this experience needs to be incorporated into the infant’s daily routine in anticipation of their discharge especially as they spend more time sleeping in supine. The addition of prone play or rest time following nipple feeding can be encouraged and modeled for parents by therapists as well
Physical Therapy Intervention In Neonatal Intensive Care Unit

as nursing staff. The importance of supine sleeping is usually modeled for and emphasized to parents prior to the time of a preterm infant’s hospital discharge. Ideally, this instruction is coupled with acknowledgment of the importance of “tummy time play.” Handouts on tummy time activities in multiple languages are available at http://www.pathways.org/awareness/parents/tummy-time as well as from Children’s Healthcare of Atlanta at http://www.choa.org/childrens-hospital-services/orthopaedics/programs-services/orthotics-and-prosthetics/tummy-time-tools.

The importance of variable play positions on sensorimotor development is evident in studies of typically developing infants. Majnemer and Barr (2005) determined from analysis of parentally completed “infant behavior diaries” that prone play or “tummy time” was seldom incorporated into an infant’s daily routine. At four months, more than 30% of 52 infants were never placed in prone and 75% spent less than 20 min in prone daily. Majnemer and Barr also determined that the average time four- to six-month-olds spent in supported swing or infant seat sitting was 4 hr per day. In general, infants with little or no prone activity time scored lower on the Alberta Infant Motor Scale (AIMS) at four months and on the Peabody Developmental Motor Scales (PDMS) at six months. Another investigation among typically developing term infants at four months revealed that most of their alert time was spent being held and supported in sitting (Dudek-Shriber & Zelazny, 2007). Sixty of the 100 infants spent 30 min or less in prone daily. In comparison, the median time infants were held in sitting was two-and-a-half hours daily in addition to the three-and-a-half hours they spent positioned in sitting each day. Infants who spent less than 1 hr and 20 min in prone were more likely to demonstrate delayed antigravity skills in prone, supine, and sitting as measured by the AIMS. The influence of positioning on early development of full-term infants does not necessarily have long-term consequences. The results nevertheless do support positioning and the environment of play as important for infants at risk for developmental delays.

In a study of caregiver handling of preterm infants during dressing, bathing, and play, Murney and Campbell (1998) reported infrequent use of the prone position. The limited ability of infants with diffuse or focal CNS damage to enjoy movement play in a variety of positions is a consideration when planning interventions. Comparison of age- and gender-matched infants three- to eight-months-old with and without positional plagiocephaly revealed a significant difference in supportive sitting time in infant seats and swings but not in prone playing time (Kennedy, Majnemer, Farmer, Barr, & Platt, 2009). Most of the infants studied spent brief times playing in prone, but development of more mature motor skills as measured by the AIMS was positively correlated with prone play duration regardless of plagiocephalic deformity. Fetters and Huang (2007) investigated the influence of sleep, play, and feeding positions on motor development through nine months CA in low-risk term infants and preterm infants with and without white matter disease (WMD) such as periventricular leukomalacia (PVL). Supine sleeping did not have a negative effect on motor development while prone sleep and play had a positive effect. The majority of the infants played and were fed in either supine or sitting. A large percentage of infants slept in prone at least part of the time and this is reflected in higher AIMS scores at one month regardless of GA at birth or CNS status. At five
months, sleeping and playing in prone were associated with higher AIMS scores. At nine months, a predominance of play in sitting was negatively associated with AIMS scores.

Although the studies cited primarily focus on infant development between four and nine months, family education and instruction at the time of the infant’s discharge form the foundation for the practice of varying sleep, play, and feeding positions until the infant becomes mobile. Through a preterm infant’s hospital course, persistent irritability in any position can be a signal of discomfort or stress that should be evaluated. Sources of infant irritability in a particular position include: GERD, constipation, intestinal gas, atelectasis, fatigue from increased work of breathing, weakness and inability to move because of too much or too little confinement, too little stability, and limited or too much sensory input. With an understanding of the source(s) of irritability, therapists can modify the position or environment and reintroduce the experience. They can, in turn, help parent to do the same rather than simply avoiding new or challenging experiences for their infant.

Enhancement of Trunk Mobility and Diaphragmatic Breathing

Adequate diaphragm control for ventilation is required in order for an infant to enjoy movement during periods of alertness. Adequate lower esophageal sphincter function and diaphragm control are needed to prevent reflux of gastric secretions and food into the esophagus or pharynx while the infant’s trunk provides a stable base for extremity or neck movement. These challenges are most evident among but not limited to infants with GERD and CLD or bronchopulmonary dysplasia (BPD). Premature birth is associated with reduced lung function during at least the first months of life (Friedrich, Stein, Pitrez, Corso, & Jones, 2006) and some level of airway obstruction has been identified in pulmonary function studies of preterm infants with no history of neonatal respiratory disease. Friedrich and colleagues (2006) determined that for each week of increased GA at birth, preterm infants gain an average 7% increase in mid-range forced expiratory flow or the efficiency of exhalation. Limitations in air flow were thought to result from persistently small diameter airways in the distal bronchial tree as well as decreased stability of these small airways (Friedrich et al., 2006). In other words, most prematurely born infants move less air out of their lungs during exhalation than a comparable size full-term infant would.

Among preterm infants 34 weeks PMA and older, a challenge to antigravity movement is that postural muscles are often used as assistive respiratory muscles. With an increased oxygen requirement imposed by active movement or nipple feeding, increased respiratory rate and recruitment of accessory respiratory muscles such as the trapezius and levator scapulae are more likely to occur. In addition to decreased efficiency of exhalation due to small, distal airway obstruction, infants with CLD can develop altered breathing patterns including a longer delay between diaphragmatic contraction and detectable initiation of inspiratory air flow, possibly because of decreased lung compliance (Hutten et al., 2010). In our experience, thoracic spinal extension and scapular retraction are postures used by preterm infants to stabilize the chest wall in an attempt to improve the efficiency of diaphragmatic contraction during active movement and nipple feeding. This, however, often limits the infant’s exploratory extremity movements, and swallow-breath coordination...
FIGURE 7. By distraction of the lower ribs toward the pelvis in a manner similar to maturely coordinated abdominal muscles, the diaphragm has a more stable base from which to function and the extremities have more proximal stability from which to move. In this picture, costal border support is used to support the infant’s tolerance of supine lying.

while nipple feeding. Consequently, fatigue as indicated by irritability, drowsiness, tachypnea, increased work of breathing, and/or diminished coordination should be anticipated among preterm infants. As the preterm infant engages in more antigravity movement during routine care as well as attempts the intake of larger volumes by nipple feeding, the infant’s need for more frequent and/or longer duration rest periods also should be anticipated.

The supine position is particularly challenging for infants with CLD, GERD, or both of these conditions. Using the maximum inspiratory pressure as a direct measure of diaphragm strength or work load, Dimitriou and colleagues (2002) found supine and semi-upright supine to be more demanding than prone lying, but that oxygen saturation was significantly higher in semi-upright positions in comparison to supine lying. Clinically, caregivers observe that some infants recover from low oxygen saturation rapidly in supine while nested in a quiet alert state but require additional oxygen support during routine care or feeding. Tolerance of supine can be improved by elevation of the head of the bed as well as planning intervention before feeding occurs. During periods of supine movement and rest, therapists and other caregivers can assist by stabilization of the lower ribs in alignment with the pelvis. By distracting the lower ribs toward the pelvis, a function of the abdominal muscles, the diaphragm has a more stable base for contraction and the legs have more proximal stability from which to move (Figure 7).

While supine or semi-upright in a caregiver’s lap, an infant’s midline head, trunk, and pelvic alignment can be supported by the positioning of the caregiver’s legs.
FIGURE 8. This infant is in a position of semi-upright supine on a caregiver’s lap. The caregiver is sitting in a chair with their feet on a stool that places the infant at approximately a 45 degree angle. With the infant supported in this position, their muscles of shoulder elevation and scapular retraction can be gently lengthened as the caregiver passively lowers and adducts the shoulders as well as protracts the scapulae. With the use of these accessory respiratory muscles limited, the infant can experience upper extremity movement toward the midline while depending upon diaphragmatic breathing.

With this support provided, the therapist can then gently lengthen the muscles of shoulder elevation and scapular retraction while passively lowering and adducting the shoulders as well as protracting the scapulae. With the use of these accessory respiratory muscles limited, the infant can experience upper extremity movement toward the midline while depending upon diaphragmatic breathing (Figure 8). With trunk and pelvic alignment maintained in supine, a therapist can facilitate abdominal muscle control by gently lengthening spinal extension muscles with passive elevation of the pelvis in a posterior tilt. From this position, the infant can experience midline head and trunk orientation and/or lower extremity movement while depending upon diaphragmatic breathing (Figure 9). Simply trusting their ventilatory capacity in supine or elevated supine positions without assistive respiratory muscles is a stressful challenge for some infants to meet before extremity movement or social interaction is possible.

Sidelying presents a ventilatory challenge for some infants with GERD as well as those with persistent pulmonary insufficiency. The infant may initially prefer one side to alleviate reflux symptoms or decrease demand on areas of chronic pulmonary infiltration or atelectasis. As feeding volume requirements increase, each sidelying position presents a different challenge for infants with reflux. Right sidelying facilitates gastric emptying immediately following feeding but can also facilitate reflux. Left sidelying can delay gastric emptying but avoid reflux (van Wijk et al., 2007). In our experience, because a neonate’s rib cage is flexible and primarily
FIGURE 9. With trunk and pelvic alignment maintained in supine, a caregiver can assist immature abdominal muscle control by gently lengthening spinal extension muscles with passive elevation of the pelvis into a posterior tilt. From this position, the infant can experience midline head and trunk orientation and/or lower extremity movement.

cartilaginous, the volume of the weight-bearing side of the chest can be significantly decreased in sidelying. Furthermore, we have observed that an infant may be comfortable resting on the side of diminished pulmonary function, but irritable resting on the other side with limited expansion of lobes depended upon for compensation. Even after the pulmonary condition has resolved or reflux symptoms have been effectively treated, habitual breathing patterns and limited soft tissue extensibility may persist and be reflected in poor tolerance of a specific sidelying position.

In order for an infant to maintain adequate ventilation in sidelying without accessory respiratory muscle use and trunk extension, elevation of the head of the bed is once again an important first step. While posteriorly cupping the infant’s head and pelvis, a therapist can passively flex the thoracic spine to neutral. Maintaining adequate oxygen saturation without tachypnea and tachycardia is the initial goal. Because accessory respiratory muscle use is typically symmetrical, the sidelying position may limit the infant’s reliance on accessory muscles. The infant’s own weight is usually sufficient to cup the lower shoulder anteriorly and protract the scapula. When ventilation is not a challenge in sidelying, an infant can interact with caregivers and enjoy exploratory movement of the un-weighted arm and leg. While being held by a caregiver in sidelying, the problem of restricted ventilation of the lower, weight-bearing chest can be resolved by simply elevating the infant.
While being held by a caregiver in sidelying, the problem of restricted ventilation of the lower, weight-bearing chest can be resolved by simply elevating the infant to approximately a 45 degree angle. In this elevated sidelying position, the weight-bearing shoulder can be held in overhead flexion with the scapula protracted to limit accessory respiratory muscle use while ventilation is no longer restricted.

Elevated sidelying, the weight-bearing shoulder can be held in overhead flexion with the scapula protracted to limit accessory respiratory muscle use (Figure 10). Elevated sidelying with lateral trunk flexion is a position in which ventilation of the lower lung is enhanced. While gaining endurance in this position may be an initial goal for an infant with CLD, alternate positioning to each side can become a valuable rest and recovery position for the infant during nipple feeding or antigravity movement.

Prone lying is frequently the preferred position for rest and recovery among infants, especially those with GERD and CLD, but horizontal prone can be a challenge. In elevated prone with the head above the stomach level, reflux symptoms are less likely to occur. This elevated prone position can occur on a caregiver’s chest, at their shoulder, across their lap, or in the infant’s bed. By gently positioning both arms overhead while the infant is in an elevated prone position, the scapulae are bilaterally protracted, use of accessory respiratory muscles is limited, and diaphragm function is enhanced. Initially, some infants only tolerate overhead flexion of the arm on one side. An additional benefit of positioning the infant across a caregiver’s lap is the potential to eliminate any pressure on a full stomach that enhances diaphragm excursion for inspiration and decreases the potential for emesis. If the infant is not trying to actively lift their head, flexion of the trunk can occur as the infant relaxes across the caregiver’s thigh (Figure 11). In this elevated prone position, the infant can burp and pass gas and stool with decreased potential for emesis following feedings. An infant can also fall asleep, engage in head lifting and/or...
kicking, as well as enjoy deep tactile stimulation of their back and soles of their feet in this elevated prone position. Infants can be carried in an elevated prone position with overhead shoulder flexion, weight off the abdomen, and the head elevated above the stomach (Figure 12). In our experience, parents coached through and reinforced for use of elevated prone positions following feedings seem to transition well to “tummy time play” at home.

Promotion of Antigravity Movements

Green, Mulcahy, and Pountney (1995) provide evidence that typical infant development includes a relatively predictable progression of increasing postural stability, controlled weight shifting, and isolated limb movement. More than 90% of the developmental changes they observed among 18 infants with typical development occurred after postural control was concurrently evident in both prone and supine. Their results suggest that strength and postural control in both prone and supine are required before even brief symmetrical sitting is achieved. Green et al. also observed that functional movement was influenced by the surface upon which an infant was placed and that infants initially reverted to less mature postures when performing movements associated with orientation, reaching, and contact responses with either their hands or feet.

Characteristics of preterm infant’s early antigravity movements have been documented and compared between full term and preterm infants. From two to four months CA, significant differences between full term and preterm infants are evident in postural adjustments and in extremity movements during reaching and
Infants can be carried in this elevated prone position with weight off the abdomen and the head elevated above the stomach. This infant has responded to the position of the caregiver’s arm by upper extremity flexion with shoulder internal rotation and adduction. Positioning both shoulders in greater overhead flexion over the caregiver’s arm than is illustrated by this photograph, can limit accessory respiratory muscle use while an infant recovers from the work of feeding or a stressful event.

Early patterns of spontaneous arm waving and kicking provide the basic patterns that infants elaborate into more complex, controlled reaching and environmental exploration with both hands and feet. Links between these initial spontaneous antigravity extremity movements and early cognitive skills as well as complex prehension and manipulative skills have been confirmed by research.
Galloway, 2009; Heathcock, Lobo, & Galloway, 2008). Associations between initial walking patterns and kicking as well as supported treadmill stepping response characteristics have been confirmed by several studies (Jeng, Chen, Tsou, Chen, & Luo, 2004; Luo et al., 2009). There is also evidence, however, that differences remain between preterm and full-term infants as they develop reaching and locomotion skills that are neither consistent nor predictive of significant morbidity or guarantees of normality (Fallang et al., 2003a).

Between 35 and 37 weeks PMA, as preterm infants gain endurance and tolerate multiple positions without physiologic compromise, they begin to include more antigravity components in their exploratory movements. Emerging postural responses can be evident during transitions out of and back into the infant’s bed as well as during supported upright at various angles during feeding and carrying. In association with diaper and clothing changes, vigorous extremity movements unrelated to stress behaviors seem at times to make the process quite difficult. It is during these periods of routine caregiving while infants are alert for expanding periods of time that therapists can teach parents to wait for responses as well as the methods to facilitate their infant’s antigravity movement within these functional caregiving activities.

The opportunities for preterm infants to engage in antigravity movement during caregiving in the NICU environment as well as post-discharge have been documented as part of an investigation of the construct validity of the Test of Infant Motor Performance (Murney & Campbell, 1998). Following analysis of videotapes of caregiving activities (bathing and dressing) and interactive play scheduled 1 hr before feeding, the authors determined that the average duration of handling was 13.9 min with a range of 7 min to 18 min among infants 33–41 weeks PMA. The majority of infants in the entire sample from 33 weeks PMA to 12 weeks CA were exposed to at least three different positions during each cycle of care and play. Among 35–37 weeks PMA infants preparing for hospital discharge as well as during their initial week following discharge, these handling periods occur at least eight times a day in association with their need to feed approximately every 3 hr. Consequently, infants can have multiple 10–15 min opportunities for antigravity movement and interactive responses daily if their caregivers assist them with proximal stability and wait for their active responses.

As infants reach 35–37 weeks PMA, one of the first measures needed to enhance their persistence in spontaneous antigravity extremity movement is gradual elimination of restrictive swaddling and nested bedding. As these same infants transition out of an isolette and into an open bed, nesting needs to be gradually eliminated so infants can experience spontaneous movement against a firm surface and gain self-calming capacity. The findings of Green and colleagues (1995) identify different responses to a firm surface among infants with less mature levels of postural control in contrast with those having more mature levels of control. The swaddling and nesting that helps calm infants may also provide shoulder and pelvic support they still depend upon for control of their posture and extremity movement. A similar degree of nesting may however frustrate a more mature infant who is able to shift their center of gravity and isolate extremity movements provided the opportunity on a firm surface.
Promotion of Supine Anti-Gravity Movement

Among maturing preterm infants, supine antigravity movements typically occur with more control in the lower extremities before the upper. The possible reasons for this are discussed by Heathcock and Galloway (2009) in their comparison of foot reaching with hand reaching skill development among four- to six-month-old infants. In order for less than 40 weeks PMA infants to kick and reach while supine, they typically need trunk and proximal joint stability before they are able to transition from movements in a relatively horizontal plane into more vertically directed movements. Antigravity leg movement can be encouraged by a caregiver assisting the abdominal muscles with lifting the pelvis into a posterior tilt. Antigravity arm movement can be encouraged by a caregiver assisting the pectoral muscles with cupping the shoulders ventrally. These two Neurodevelopmental Treatment or NDT-based facilitation methods are explained in detail by both Bly (1999) and Boehme (1990). Rather than deciding upon a specific time or duration for antigravity movement, therapists can assist parents in identification of optimal times during caregiving for support of antigravity extremity movement. By teaching parents methods for proximal support, they can help their infant extend the duration and variation of extremity movement multiple times daily in the functional context of caregiving.

Promotion of Prone Antigravity Movements

Prone antigravity movements typically include neck rotation and head lifting with increasing degrees of thoracic spinal extension as the infant matures and gains strength. These movements typically occur while a caregiver supports an infant prone on their chest or lap at variable angles to the horizontal plane as well as when a caregiver holds them suspended in open space during multiple caregiving tasks. The extent to which both an infant’s trunk stability and trunk-to-pelvic alignment are assisted by the caregiver is reflected in the quality and duration of the infant’s head lifting and interactive orientation responses. Placement of one of the caregiver’s hands firmly over the infant’s pelvis and hips may provide sufficient stability to encourage head lifting as the visual stimuli or the angle of the caregiver’s lap change. Additional stability and alignment assistance can be provided by the caregiver’s hands positioned firmly at one or both sides of the trunk, distracting the infant’s lower ribs down toward the pelvis and assisting caudal-ward weight transfer. These are also NDT-based methods for facilitation of head lifting in prone that are explained in detail by both Bly (1999) and Boehme (1990).

Promotion of Antigravity Movements in Supported Sitting

Assistive measures for increasing an infant’s tolerance of and endurance in the sitting position as well as methods to facilitate head lifting and extremity movements in stationary sitting are discussed previously in this article in Section “Increased time in upright position.” Typical caregiving routines at the time of discharge, however, also include transitions into and out of sitting as well as movement through space while in a sitting position. The complexity of an infant’s responses to these transitional movements varies with the support and alignment assistance provided for the trunk and neck, with the angle of the head and trunk relative to vertical,
and with the degree of free movement allowed for the extremities. Therapists can teach a caregiver to lift their infant or move them from supine or prone into sitting while providing trunk to pelvic alignment and stability as well as to pause during the movement and wait for the infant’s emerging neck rotation or lateral flexion responses. These NDT-based methods for facilitation of postural responses during movement in and out of sitting, carrying, kicking, and reaching in supported sitting are also explained in detail by both Bly (1999) and Boehme (1990).

**Neurodevelopmental Techniques**

Neurodevelopmental treatment or NDT techniques are appropriate to include within movement therapy as preterm infants reach 35–37 weeks PMA (Figure 3). These techniques have already been described in the previous section as the basis for many of the methods employed by therapists to promote antigravity movements. Although in wide use and woven into the treatment repertoire of many physical therapists, NDT as a primary intervention program within the NICU nevertheless lacks the support provided by statistically significant, measurable long-term results from large randomized controlled trials.

A controlled clinical trial provides support for the application of an NDT program for preterm infants in the NICU (Girolami & Campbell, 1994). The study is referenced as evidence supporting movement intervention in the guidelines for NICU practice (Sweeney, Heriza, Blanchard, & Dusing, 2010). The preterm infants were at high risk for long-term developmental delay and had three or more positive neurological findings on the Neonatal Behavioral Assessment Scale (NBAS) at 34–35 weeks PMA. Nine preterm infants received NDT, 10 preterm infants received social stimulation, and eight full-term infants received no intervention. The intervention (Girolami & Campbell, 1994) was designed to improve head control, midline orientation, hands-to-mouth activity, and antigravity movements of the extremities. The preterm control group received social stimulation in each of the four positions. NDT-based treatment or social stimulation was provided twice daily for up to 15 min for at least seven but up to 17 days. Following intervention, infants were evaluated by examiners blind to group assignment using the NBAS and a supplemental motor test based on the Neurological Assessment of the Preterm and Full-Term Newborn Infant (Dubowitz & Dubowitz, 1981).

The results indicated that the full-term control group performed significantly better than either of the preterm groups on the motor performance cluster of the NBAS, and the preterm control group performed better than other groups on the autonomic regulation cluster. On the supplemental motor test assessment of postural control, the preterm infants who received NDT treatment outperformed both control groups on spontaneous behavior items and the preterm control group on elicited activity items.

This study has not been replicated and there are no published randomized controlled trials with a larger sample size that have reported statistically significant long-term outcomes supporting use of NDT as a primary intervention program in the NICU. A replication, however, is under way in a large clinical trial in Norway (http://www2.uit.no/ikbViewer/page/publikum/prosjekter/prosjekt?p_document_id=216556).
RESEARCH ON MOTOR INTERVENTION IN NICU

In a review of published intervention studies among infants and toddlers at risk for developmental delay, 17 studies were identified that occurred within a NICU setting (Blauw-Hospers & Hadders-Algra, 2005). The content of these programs was described as including combinations of auditory, tactile, visual, and/or vestibular stimulation as well as calming or stress reduction measures and passive handling. Ten of the NICU intervention studies provided no evidence of positive or negative effect on motor development while seven of the studies primarily implementing NIDCAP interventions did support at least short-term positive effects on infant motor development. Two of the intervention programs occurring following NICU discharge that documented significantly greater motor skill improvement than their control groups provided descriptions of developmental programs and parent involvement in the movement play (Barrera, Cunningham, & Rosenbaum, 1986; Lekskulchai & Cole, 2001). Blauw-Hospers and Hadders-Algra (2005) concluded that substantial evidence supported the benefits of developmental training interventions after NICU discharge in which parents learned how to assist and encourage their infant’s motor development. They also concluded that programs limited to passive handling techniques were not beneficial while those programs that were focused on specific tasks and stimulated infants to actively explore use of the emerging movement skill can have a positive influence.

There is evidence supporting the benefits of movement training during the early months of postnatal life but none supporting this degree of handling and stimulation while infants are in the NICU. Among both maturing full term and preterm infants, these initial anti-gravity movements can increase in complexity, frequency, and duration following specific daily training protocols (Heathcock & Galloway, 2009; Heathcock et al., 2008). In the home setting, following eight-week, caregiver-based daily training programs, infants with initially two months CA increased the accuracy, frequency, and duration of reaching as well as hand or foot contact with an object. By four months CA, the prematurely born infants participating in the training programs performed more optimally than those prematurely born infants not receiving training. In comparison with full-term infants at four months, the infants who participated in the training programs demonstrated equivalent skill for several movement characteristics.

Although neither of these studies (Heathcock & Galloway, 2009; Heathcock et al., 2008) was conducted in the NICU setting or with infants less than two months CA, the content of the movement training provides some helpful guidance to therapists teaching parents how to encourage their infant’s engagement in antigravity movement leading up to and following hospital discharge. The movement training programs focused on task-specific activities provided by parents. The activities involved the active participation of the infant in multimodal, interactive tasks. These interactive tasks were not only encouraged during the 10-min daily training sessions, but were also likely to be repeated during routine care and play many other times during each day as the infant’s responses improved. A good resource summarizing the available Cochrane Reviews on the evidence on effects of a variety of interventions is the chapter on the “Special Care Nursery” in Physical Therapy for Children, 4th ed. (Kahn-D’Angelo, Blanchard, & McManus, 2012).
Because there is a paucity of evidence on exercise programs in the NICU, clinicians are advised to remain current on the scientific literature in order to identify the most effective interventions to promote motor development in the NICU. Meanwhile, the evidence from the large clinical trial by Lekskulchai and Cole (2001) and the movement training protocols designed by Heathcock et al. (2008; see also, Heathcock & Galloway, 2009) provide evidence for recommending home exercise following hospital discharge.

**Declaration of interest**
The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

**ABOUT THE AUTHORS**

Eilish M. Byrne, PT, DSc, PCS, is the Professional Development, Education and Research Specialist for the Department of Rehabilitation Services working in the Neonatal Intensive Care Unit at Lucile Packard Children’s Hospital, Palo Alto, CA.

June Garber, PT, MACT, is a Senior Physical Therapist working in the Neonatal Special Care Nurseries at Emory University Hospital Midtown and Grady Memorial Hospital as well as Professor Emerita at Emory University, School of Medicine Division of Physical Therapy, Atlanta, GA.

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